# Assignment 3 (CT) Answers

## Part 1: Choose the correct answer:

(1) The fundamental measurement made by a CT scanner is the:

- ○ (A) Sorting of CT numbers
- ○ (B) Determination of gray scale
- ○ (C) Pixel density
- ◉ (D) Relative x-ray attenuation
- ○ (E) Voxel atomic number

(2) Which of the following has a Hounsfield unit value of approximately - 90?

- ◉ (A) Fat
- ○ (B) Gray matter
- ○ (C) Water
- ○ (D) Bone
- ○ (E) Lung

(3) Tissue characterization is difficult because the value of a CT number may change because of:

- ○ (A) Window level
- ○ (B) Window width
- ○ (C) Tube current
- ○ (D) Scan time
- ◉ (E) Volume averaging

(4) The measured x-ray transmissions from a single CT fan beam through a patient is called a:

- ○ (A) Filter
- ○ (B) Back-projection algorithm
- ○ (C) Tomographic slice
- ○ (D) Primary beam
- ◉ (E) Projection

(5) Which image reconstruction algorithm is used in current commercial CT scanners?

- (A) Two-dimensional Fourier transform
- (B) Three-dimensional Fourier transform
- (C) Back projection
- (D) Filtered back projection
- (E) Algebraic reconstruction algorithm

(6) If a CT display is set at a window width of 100 and a window center of 50, the:

- (A) HU value of water changes to 50
- (B) White matter will look gray
- (C) Gray matter will look white
- (D) Bone will look black
- (E) Lung will look white

(7) The CT image display contrast:

- (A) Must be selected prior to the x-ray exposures
- (B) May be altered after the CT scan
- (C) Does not modify the appearance of the CT image
- (D) Can be used to change the Hounsfield unit values of image data
- (E) Uses an array processor

(8) Which of the following cannot be used to process CT images?

- (A) Window/level adjustment
- (B) Multiplanar reformatting
- (C) Phase encoding
- (D) Volume rendering
- (E) Shaded-surface display

(9) CT anode heat loading increases with all of the following except an increase in:

- (A) Tube voltage
- (B) Tube current

- (C) Scan time
- (D) Section thickness
- (E) Number of sections

(10) CT collimators are:

- (A) Variable for different section thickness
- (B) Not necessary for helical scans
- (C) Usually made out of Plexiglas
- (D) Bowtie shaped
- (E) Cooled using fans

(11) Which would not likely be used as detectors in CT scanners?

- (A) Bismuth germanate
- (B) $CdW0_4$
- (C) Xenon gas
- (D) NaI
- (E) Air ionization chambers

(12) Fourth-generation CT detectors are frequently made of:

- (A) Low-pressure air ionization chambers
- (B) Geiger tubes
- (C) $CdW0_4$
- (D) High-pressure xenon
- (E) Selenium

(13) Electron-beam CT can acquire a CT image in:

- (A) Less than I millisecond
- (B) 1millisecond
- (C) 8 millisecond
- (D) 25 millisecond
- (E) 50 millisecond

(14) The main advantage of helical CT over conventional (axial) CT is improved:

- (A) Spatial resolution
- (B) Low contrast detection
- (C) Data acquisition rate
- (D) Patient dose
- (E) Image reconstruction time

(15) Multislice CT improves the utilization of the:

- (A) X-ray tube output
- (B) Collimators
- (C) Bow tie filter
- (D) X-ray detectors
- (E) Analog-to-digital converters

(16) CT fluoroscopy minimizes radiation doses by using lower:

- (A) Filtration
- (B) Voltage
- (C) Current
- (D) Collimator thickness
- (E) Field of view

(17) The theoretically best possible CT resolution for a $512^2$ matrix and 25 cm FOV is:

- (A) 0.5 Ip/mm
- (B) 1.0 Ip/mm
- (C) 2.0 Ip/mm
- (D) 5.0 Ip/mm
- (E) 10.0 Ip/mm

(18) CT scanner spatial resolution could improve with an increase of:

- (A) Focal spot size
- (B) Detector elements size

- (C) Tube voltage
- (D) Scan time
- (E) Reconstruction matrix

(19) Visibility of small high-contrast CT lesions would most likely improve with decreasing:

- (A) Patient dose
- (B) Scan time
- (C) Field of view
- (D) Slice thickness
- (E) Tube voltage

(20) Visibility of large low-contrast CT lesions may improve with increasing:

- (A) Filtration
- (B) mAs
- (C) Matrix size
- (D) Display window width
- (E) Size of film image

(21) Image noise is not affected by the:

- (A) Section thickness
- (B) Reconstruction algorithm
- (C) Patient thickness
- (D) mAs
- (E) Display settings (window/level)

(22) The difference in x-ray attenuation between white (40 HU) and gray matter (50 HU):

- (A) Is 0.1%
- (B) Is 1%
- (C) Is 10%

- (D) Is 25%
- (E) Cannot be determined

(23) Partial volume artifacts in CT are generally reduced by reducing the:

- (A) Section thickness
- (B) Scanning time
- (C) Image matrix size
- (D) Focal spot size
- (E) Tube voltage

(24) CT number depends on all the following except:

- (A) Beam hardening
- (B) Tissue heterogeneity
- (C) mAs
- (D) X-ray attenuation
- (E) Tube voltage

(25) Ring artifacts in a third-generation CT scanner are caused by:

- (A) Kilovolt peak drift
- (B) Tube arcing
- (C) Faulty detector elements
- (D) Patient motion
- (E) Poor collimation

(26) Which of the following is least likely to be a source of CT image artifacts'?

- (A) Anode wobble
- (B) Faulty detectors
- (C) Metallic implants in patient
- (D) Limited sampling of projection data
- (E) Radiofrequency source near CT scanner

(27) Which of the following is not a source of CT artifacts'?

- (A) Patient motion
- (B) Metal implants
- (C) Beam hardening
- (D) Low tube current
- (E) Faulty calibration data

(28) Representative patient doses in CT are expected to include all the following except:

- (A) Head skin dose of 40 mGy (4 rad)
- (B) Head central axis dose of 40 mGy (4 rad)
- (C) Body skin dose of 20 mGy (2 rad)
- (D) Body central axis dose of 40 mGy (4 rad)
- (E) Embryo dose (abdomen CT) of 15 mGy (1.5 rad)

(29) The dose to the fetus during an abdominal CT scan would not increase with increasing:

- (A) Patient size
- (B) Tube voltage
- (C) Tube current
- (D) Scan time
- (E) Number of sections

(30) The scattered radiation dose 1 meter from a patient undergoing a head CT scan is:

- (A) Less than 0.04 mGy (below 4 mrad)
- (B) About 0.04 mGy (4 nuad)
- (C) About 0.4 mGy (40 mrad)
- (D) About 4 mGy (400 mrad)
- (E) More than 4 mGy (over 400 mrad)

## Answers to the MCQs

**Question 1** : Correct answer is D
**Explanation:** Relative attenuation of x-rays, because the Hounsfield units associated with each pixel are linearly related to the average linear attenuation coefficient of the tissue associated with this pixel.

**Question 2** : Correct answer is A
**Explanation:** Fat is -90 HU.

**Question 3** : Correct answer is E
**Explanation:** Volume averaging, because the CT number is an average of the linear attenuation coefficients of the materials within the voxel.

**Question 4** : Correct answer is E
**Explanation:** A projection is a profile of transmitted x-ray intensities through the patient at any given location of the x-ray tube, with up to 1,000 projections acquired and used to reconstruct the CT image.

**Question 5** : Correct answer is D
**Explanation:** Filtered back projection is currently used on virtually all commercial CT scanners to reconstruct images from projection data.

**Question 6** : Correct answer is B
**Explanation:** White matter will be in the middle of the display range.

**Question 7** : Correct answer is B
**Explanation:** Changing the display contrast (window center and width) alters the appearance of the CT image but not the reconstructed image data (HU).

**Question 8** : Correct answer is C
**Explanation:** Phase encoding is used in magnetic resonance imaging and has no connection with CT.

**Question 9** : Correct answer is D
**Explanation:** Section thickness selection does not directly affect x-ray heat loading.

**Question 10** : Correct answer is A
**Explanation:** The collimators are located at the x-ray tube and detectors and have a variable width that defines the CT section thickness.

**Question 11** : Correct answer is E
**Explanation:** Because air (obviously) absorbs a negligible amount of radiation, an air ionization chamber would be a terrible CT x-ray detector.

**Question 12** : Correct answer is C
**Explanation:** Fourth-generation CT systems use solid state detectors such as $CdW0_4$; gas detectors are used only in third-generation scanners.

**Question 13** : Correct answer is E
**Explanation:** EBCT can acquire a CT image in a period as short as 50 milliseconds.

**Question 14** : Correct answer is C
**Explanation:** Fast patient data acquisition is the major benefit of helical CT.

**Question 15** : Correct answer is A

**Explanation:** The principle benefit of multislice CT is the improved utilization of the x-ray tube output.

**Question 16** : Correct answer is C
**Explanation:** Low current values are normally used in CT fluoroscopy (20 to 50 rnA) to reduce doses to patients and operators.

**Question 17** : Correct answer is B
**Explanation:** 1 lp/mm; a matrix size of 512 can display about 250 lp over a region that is 250 mm (25 em) and that corresponds to 1 lp/mm.

**Question 18** : Correct answer is E
**Explanation:** Spatial resolution could improve with an increase in reconstruction matrix size if resolution was limited by matrix size (not focal spot or detector size).

**Question 19** : Correct answer is C
**Explanation:** Decreasing the FOV would improve spatial resolution.

**Question 20** : Correct answer is B
**Explanation:** Low-contrast objects are difficult to see because of noise, and increasing the mAs increases the number of photons used and hence reduces CT image noise.

**Question 21** : Correct answer is E
**Explanation:** The CT display will not affect the image noise contained in the image data set itself. However, modifying the display settings would affect the appearance of any noise.

**Question 22** : Correct answer is B
**Explanation:** By definition lO HU always corresponds to a difference in attenuation coefficient of 1% relative to water (RU is a relative attenuation scale in which water is equal to 0).

**Question 23** : Correct answer is A
**Explanation:** A lower slice thickness will reduce partial volume effects.

**Question 24** : Correct answer is C
**Explanation:** mAs will have no effect on CT numbers but will affect the precision with which they are measured (noise).

**Question 25** : Correct answer is C
**Explanation:** A faulty detector reading on third-generation scanners gives rise to ring artifacts. The closer the artifact to the image center, the more central the detector element that is faulty in the linear detector array.

**Question 26** : Correct answer is E
**Explanation:** Radiofrequency sources are unlikely to have any effect on the x-ray detection and therefore should produce no artifacts.

**Question 27** : Correct answer is D
**Explanation:** Low tube currents give rise to noticeable quantum mottle effects hut not to artifacts per se.

**Question 28** : Correct answer is D
**Explanation:** A body central axis dose would be about 10 mGy (1 rad), which is about half the skin dose.

**Question 29** : Correct answer is A
**Explanation:** Increasing the patient size will always reduce the embryo dose because there is more attenuation of the x-ray beam.

**Question 30** : Correct answer is B
**Explanation:** Skin dose to patient will be about 40 mGy (4 rad), and the scatter will be about 0.1% of this level at a distance of 1 meter.

## Part 2: Answer true or false for the following questions

**1) In computed tomography (CT):**

**A.** third generation scanners rotate detector array and tube
**B.** xenon gas can be used as a detector
**C.** slice width affects spatial resolution
**D.** tube anode/cathode axis is perpendicular to the detector array
**E.** as slice thickness increases, the partial volume effect tends to decrease

**A.** true **B.** true **C.** true **D.** false **E.** false
In a 4th generation scanner, the detectors are stationary, only the X-ray tube rotates whereas in 3rd generation scanners both the detector array and tube rotate. Spatial resolution deteriorates with increased slice width or increased pixel size. The tube anode/cathode axis is perpendicular to the fan beam plane and parallel to the detector array. Increasing slice thickness will increase the partial volume effect.

**2) Spatial resolution in CT depends on:**

**A**. slice thickness
**B**. slice spacing
**C**. pixel size
**D**. window level
**E**. matrix size

**Answer:**
**A.** true **B.** false **C.** true **D.** false **E.** true
Spatial resolution is the ability to distinguish two objects. It is improved by:

- decreasing slice thickness
- increasing matrix size
- decreasing pixel size
- reducing the field of view

Below a certain pixel size, spatial resolution is further limited by the size of the focal spot, collimators, number and size of detectors, and spacing between the detectors. Low contrast spatial resolution is limited by the noise in the image.

**3) In computed tomography:**

**A.** the pixel value represents the linear attenuation coefficient in a voxel

**B.** Compton interactions predominate in the patient
**C.** 5 mm copper filtration is required
**D.** fat has a typical value of -100 Hounsfield units
**E.** narrowing of the window width decreases contrast in the processed image

**Answer**

**A.** true **B.** true **C.** false **D.** true **E.** false

The brightness or grey scale value of each pixel represents the average linear attenuation coefficient of the contents of the corresponding voxel. Nearly all CT is operated at a kVp of 140, at these high energies Compton interactions predominate in the patient. A 'bow-tie' filter is used providing a filtration equivalent to 0.5 mm of copper. Narrowing of the window width increases contrast as it allows small differences of CT number to be selected from the full range and displayed over the whole grey scale.

**4) The effective dose in CT of the abdomen will be reduced by:**

**A.** increasing the spacing between slices
**B.** increasing the mA, other factors remaining constant
**C.** increasing the number of detectors
**D.** using spiral scanning rather than selective scanning
**E.** decreasing the field of view

Answer:

**A.** true **B.** false **C.** false **D.** false **E.** false

The dose increases with the number of slices. By increasing the spacing, fewer slices will be imaged. Dose is proportional to mA. Increasing the number of detectors has no effect on dose. In spiral scanning the dose depends very much on the scan protocol and it does not always follow that doses will be lower. However in long acquisitions tube loading may be a limitation and a lower mA may be used resulting in a lower patient dose. As each slice needs to be reconstructed by all the ray paths available through the volume, all the detectors need to be used even with a smaller selected field of view (FOV). Hence selecting a smaller FOV will not affect the dose.

**5) In computed tomography:**

**A.** spatial resolution is improved by decreasing the pixel size
**B.** noise will be reduced if the slice thickness is increased
**C.** each detector has its own collimator
**D.** a xenon gas detector is more efficient than a thallium doped NaI detector
**E.** photoelectric interactions predominate in the patient

**Answer**

**A.** true **B.** true **C.** true **D.** false **E.** false

High spatial resolution imaging involves increasing the matrix size or reducing the field of view, thus decreasing the pixel size. Noise in CT may be reduced by increasing the number of photons absorbed in each voxel, by increasing slice thickness, or the pixel size. Ionization chambers are less sensitive than scintillators. The Compton process predominates in CT.

**6) In computed tomography:**

**A.** spatial resolution improves with an increase in matrix size
**B.** spatial resolution is superior to plain radiography
**C.** small quantities of calcium can have a significant effect on partial volume averaging in a voxel
**D.** noise is independent of slice width
**E.** the ability to detect low contrast details depends more on object size than pixel size in the image

**Answer:**

**A.** true **B.** false **C.** true **D.** false **E.** true

In CT spatial resolution improves with increasing matrix size. It is much poorer than plain radiography. Tiny calcifications are made visible because of partial volume averaging, as a high contrast object occupying only part of a voxel will raise the CT number for the corresponding pixel and so give rise to

image contrast. Noise may be reduced by increasing the slice thickness. The larger the object we are trying to detect the greater the number of pixels over which the noise can be averaged and better the signal to noise ratio.

**7) In computed tomography imaging:**

**A.** the partial volume effect is when the cross sectional area of the patient exceeds the internal size of the scanner
**B.** beam hardening corrections may be aided by a bow-tie filter
**C.** contrast which arises from the attenuated beam is due to photoelectric interactions
**D.** uses low power X-ray sources to lower the dose to the patient
**E.** have more than one X-ray source if they are capable of spiral scanning

**Answer**:
**A.** false **B.** true **C.** false **D.** false **E.** false
The Hounsfield unit of each pixel is a weighted average of all the constituents of the voxel. The presence of a very high attenuating material (e.g. calcium) will elevate the CT number of the entire pixel enabling something to be seen. This is partial volume averaging. Nearly all CT is operated at a tube potential of 120–140 kVp. At these energy levels Compton interactions predominate.

**8) The following are true of image quality in CT:**

**A.** using a narrower window reduces the effect of noise
**B.** increasing the slice thickness increases the effect of noise
**C.** line-pair resolution is generally better than that obtainable in film-screen radiography
**D.** the phenomenon called ‘cupping’ (abnormally lower attenuation at the centre of the CT image) is usually caused by detector malfunction
**E.** in a scan using helical (spiral) scanning resolution is improved by increasing the pitch

**Answer:**
**A.** false **B.** false **C.** false **D.** false **E.** false
Using a narrower window increases the effect of noise because each grey level would represent a smaller range of CT numbers. A bow tie filter is used to aid the process of applying a beam hardening correction by compensating for the thinner patient thickness around the outside of the patient, i.e. the ray paths have to pass through less patient nearer the periphery of the field of view. Increasing the slice thickness decreases the effect of noise because more photons are detected. Line pair resolution is only about one line pair per mm and so is much poorer than that obtainable in film-screen radiography. The phenomenon called cupping, an abnormally lower attenuation at the centre of the CT image, is caused by beam hardening as the X-ray beam passes through the patient. This artefact is compensated for by using compensatory algorithms. The pitch of a helical scan is increased by increasing the speed of the table movement. This speeds up the scanning and reduces dose but greater interpolation is needed, thus reducing resolution.